

USING GIS AND PYTHON FOR ASSESSMENT AND PRIORITIZATION
OF POTENTIAL TRANSIT PROJECTS

A Paper

Submitted to the Faculty

of

Georgia Institute of Technology

by

Eric V. Main

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science in Geographic Information Science and Technology

August 2016

Georgia Institute of Technology

Atlanta, Georgia

For Lisa and Viola

ACKNOWLEDGEMENT

I would like to express my sincere appreciation to my advisor, Dr. Drummond of the School of City and Regional Planning at Georgia Institute of Technology. Your advice, support, patience, and understanding have been invaluable in keeping me on track for a successful and timely completion of my studies.

TABLE OF CONTENTS

	Page
ABSTRACT.....	vi
CHAPTER 1. INTRODUCTION.....	7
CHAPTER 2. LITERATURE REVIEW.....	8
2.1 Sustainable Development.....	8
2.1.1 Transit Projects and Sustainable Development.....	8
2.1.1.1 Spatial Integration of Employment and Transportation.....	9
2.1.1.2 Pedestrian Access (Walking and Biking) to Work and Leisure.....	9
2.1.1.3 Protection of Natural and Biological Functions and Processes	10
2.1.1.4 Social Spaces (Public Spaces to Encourage Social Gathering).....	11
2.1.1.5 Inter-Modal Transportation Connectivity	12
2.2 Walkability and Transit	12
CHAPTER 3. DATA AND METHODS	14
3.1 Data.....	14
3.1.1 Existing Data.....	14
3.1.2 Created Data.....	15
3.2 Methods	16
3.2.1 Preparation of Existing Data/Creation of Potential Transit Projects Data..	16
3.2.2 Assessing the Sustainability of Potential Transit Projects	19
3.2.2.1 Spatial Integration of Employment and Transportation.....	19
3.2.2.2 Pedestrian Access (Walking and Biking) to Work and Leisure.....	19
3.2.2.3 Protection of Natural and Biological Functions and Processes	20

3.2.2.4	Social Spaces (Public Spaces to Encourage Social Gathering).....	20
3.2.2.5	Inter-Modal Transportation Connectivity	21
3.2.2.6	Potential Transit Projects Sustainability Scores.....	22
3.2.3	Prioritizing Potential Transit Projects.....	22
CHAPTER 4.	RESULTS	24
4.1	Sustainability Scores	24
4.2	Prioritization	24
CHAPTER 5.	DISCUSSION.....	26
5.1	Performance.....	26
5.2	Limitations.....	26
5.3	Future Directions	27
WORKS CITED	29

ABSTRACT

Main, Eric V. M.S.G.I.S.T, Georgia Institute of Technology, August 2016. Using GIS and Python for Assessment and Prioritization of Potential Transit Projects. Major Professor: William Drummond.

Increased demand for additional transit types and capacity in many American cities, combined with increased interest in, and requirements for, sustainable development have created an opportunity for the creation of systems that might streamline and automate the assessment and prioritization of future transit projects. Using the city of Atlanta as the study area, this project attempted to test the use of a combination of GIS and Python to assess potential transit projects for sustainability, and then rank them for construction priority after obtaining user input. First, five sustainability standards relating to transit projects were developed following a literature review. Next, Esri ArcGIS 10.3 was used to create eight feature classes representing five Light Rail Transit, Heavy Rail Transit, or Bike/Pedestrian Path projects in the Atlanta area. Finally, a Python script was written which assessed the potential transit projects against the sustainability standards and gave each a sustainability score, then it prompted for user input to rate the importance of a series of statements, which was used to prioritize the construction order of the projects. The final script performed as intended, producing consistent sustainable development scores for each project, while the priority of the projects changed as the user varied the importance of the statements presented, as expected. Use of the script seemed to engage users with the topic, so future directions might include assessing a larger number of users' interest in sustainable transit projects before and after using the script.

CHAPTER 1. INTRODUCTION

Among the numerous drivers for American cities considering expansion of transit types and capacity are congested roadways, tougher pollution/greenhouse gas standards, and demand from workers and businesses. Related to these issues are the increasing interest in sustainable development and increasing requirements for sustainable development. This project is about analyzing the intersection of transit and sustainable development with assessment and decision making through GIS and Python.

After choosing Atlanta, Georgia, a city with inadequate transit capacity and few types of available transit, as the general area of study, feature classes representing potential transit projects will be created using ArcGIS 10.3. Then, Python will be used to assess these projects against sustainability standards relating to transit that will be developed from a review of current literature. Finally, the Python script will prompt the user for input to be used for prioritizing the eventual construction of the potential transit projects. The end result being an answer to the research question: Can potential transit projects be assessed for alignment with sustainable development standards and then prioritized according to user preferences using GIS and an interactive Python script?

CHAPTER 2. LITERATURE REVIEW

2.1 Sustainable Development

In 1987, the Brundtland Report, from the United Nations World Commission on Environment and Development, first defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Since then, approaches to the concept of sustainable development have been discussed extensively in and between different schools of thought, from New urbanism, smart growth and the ecological city (Jepson and Edwards, 2010).

2.1.1 Transit Projects and Sustainable Development

Jepson and Edwards developed a set of 14 principles of sustainable development that seem to encompass the broad range of standards found elsewhere in the review of literature. For the purposes of this study, those sustainable development principles that can be associated with transit were chosen as benchmarks.

The five sustainable development standards that all of the potential transit projects will be evaluated against:

1. Spatial Integration of Employment and Transportation
2. Pedestrian Access (Walking and Biking) to Work and Leisure
3. Protection of Natural and Biological Functions and Processes
4. Social Spaces (Public Spaces to Encourage Social Gathering)
5. Inter-Modal Transportation Connectivity

2.1.1.1 Spatial Integration of Employment and Transportation

“Facilitated access will improve systemic connectivity and increase productivity and efficiency among the residents of the human system” (Jepson and Edwards, 2010). One model shows a significant association of the physical environment of the workplace and the community with bicycling to work, after accounting for individual factors. The perception that the streets near the workplace are dangerous for bicycling hinders bicycle commuting significantly, indicating an indirect effect of bicycle infrastructure around the workplace through its effect on perceptions of bicycling safety (Handy and Xing, 2011). Providing good quality public transit and free car parking within walking or cycling distance of major employment sites seems to encourage the inclusion of active travel in the journey to work, particularly for people who live too far from work to walk or cycle the entire journey (Jones and Ogilvie, 2012).

2.1.1.2 Pedestrian Access (Walking and Biking) to Work and Leisure

"Increasing the amount of non-motorized transportation will reduce transportation energy consumption and protect against resource depletion and pollution, as well as having positive health impacts on the residents of a community” (Jepson and Edwards, 2010). Easy access to public transportation and high frequency transport services tend to promote active commuting. Active commuting is also associated with the proximity and density of public transportation stops (Djurhuus, Hansen, Aahahl and Glumer, 2014). Offroad bikeways were consistently associated with walking between 60 and 150 min per week (Wilson, Giles-Corti and Turrell, 2012). Providing safe and convenient

environments for people of all ages and mobility levels to walk or bike for transportation and recreation is one of many important steps needed to encourage more active lifestyles (Trowbridge and Schmid, 2013). The New York City Department of Transportation is encouraging active transportation by experimenting with “road diets” for major urban streets to provide pedestrian areas and fully protected bike lanes (Trowbridge and Schmid, 2013). In one study, proximity to a new path for biking and cycling predicted an increased likelihood of a greater than 30% increase in the share of commute trips involving any active travel and a large decrease in the share of trips made entirely by car (Heinen, Panter, Mackett and Ogilvie, 2015).

2.1.1.3 Protection of Natural and Biological Functions and Processes

“Due to its reliance on nature, the sustainability of the human system requires that the integrity of natural systems be maintained” (Jepson and Edwards, 2010). Developing urban ecological networks is becoming increasingly important for sustainable urban management (Oh, Lee and Park, 2011). To encourage pedestrian travel, governments adopt pedestrian-oriented development codes, which call for tree-lined streets with vegetated medians, among other things (Silverman, 2011). The effect of open space upon the environment and human health tends to obtain less currency than economic development or the creation of jobs. Because open space originally existed plentifully as part of the natural environment, difficulties may be encountered in conceptualizing it as a necessary accompaniment to the built environment. In contrast to public capital facilities for roads, sewers, and water mains, set asides for open space remain to be fully

recognized as part of the infrastructure necessary to support living in urban areas (Griffith, 2011).

2.1.1.4 Social Spaces (Public Spaces to Encourage Social Gathering)

“Increased social contact among the residents of a community can improve the community’s ability to organize and respond to changing conditions” (Jepson and Edwards, 2010). The creation of green, civic open spaces was recognized as an important design concept in the formation of a number of the country's early cities. Philadelphia, Savannah, and New Haven were developed around squares of green open space (Griffith, 2011). Parks provide ideal open spaces for leisure-time physical activity and important venues to promote physical activity (Zhang, Lu and Holt, 2011). Greenways that offer connected linear space for trails and alternate transportation modes will also be a priority under any viable open space program. The greenway movement, fueled by concerns for physical fitness and health, helps fulfill the desire for proximity to deliberately planned space for recreational uses in urban areas (Griffith, 2011). Many benefits commonly reported by general trail users were reported in a particular study, however, the additional benefits of convenience and access, scenic views, and an enhanced social life were also reported (Corning, Mowatt and Chancellor, 2012). Nearly 40 years of research provides a body of evidence about benefits of human health, well-being, and improved function associated with experiences of nearby nature in cities (Wolf and Robbins, 2015).

2.1.1.5 Inter-Modal Transportation Connectivity

“Increased connective efficiency will (a) create the opportunity for increased frequency of interactions among the residents of a community, and (b) reduce dependency on modes that are polluting and highly energy-consumptive” (Jepson and Edwards, 2010). A diverse, multi-modal transportation system is critical for creating sustainable urban environments. Optimally, Heavy rail is a component of a larger transportation network that should include light rail, bike trails, and walkable neighborhoods. Such a system creates a variety of options for transportation users, enabling people to select what mode or modes are most appropriate for a given trip (Wickizer and Snow, 2010). Multiple transport modes within walking or cycling distance are also important factors associated with active commuting by public transportation (Djurhuus, Hansen, Aahahl and Glumer, 2014). Providing multi-modal transportation options is a key component of making walking and biking convenient (Trowbridge and Schmid, 2013). Increasingly, transit agencies in the United States are constructing light rail systems in and above freeway medians to reduce land acquisition costs, minimize traffic conflicts, increase train speeds, and minimize environmental impact (Loukaitou-Sideris, Higgins, Cuff, and Oprea, 2013).

2.2 Walkability and Transit

Since several of the standards involve things such as “spatial integration” and “pedestrian access,” a standard for what people considered to be walking distance in regards to transit had to be determined. The price of residential property within a ten-minute walk (one half mile (Dalton, Jones, Panter and Ogilvie, 2013)) from a mass transit station sells for twenty-five percent greater than the equivalent market without transit

(Silverman, 2011). Light rail can have a positive impact on property appreciation rates near urban commuting stations with properties appreciating at an annual average rate of 18.4 percentage points higher than properties farther away (Kim and Lahr, 2014). The Center for Transit-Oriented Development has estimated that by 2030, demand near transit stops in the United States will increase to include nearly twenty-five percent of the rental and buyer markets (Silverman, 2011).

CHAPTER 3. DATA AND METHODS

3.1 Data

3.1.1 Existing Data

Some of the existing data was used to show the locational relationship and connectivity to data that was created as part of this study. Other data was used as a starting point for the creation of new data. The rest of the data contained counts that were used in the sustainability assessment and subsequent prioritization calculations.

Existing data used by source and type:

- Atlanta Regional Commission
 - Shapefiles
 - Heavy Rail Transit Lines
 - Heavy Rail Transit Stations
 - Light Rail Transit
 - Railroad Lines
 - Expressways
 - Streets
 - Georgia Counties
 - Census 2010 Blocks
- City of Atlanta
 - Shapefiles
 - Atlanta Beltline Corridor

- United States Census Bureau
 - Comma Separated Values (CSV) Files
 - Longitudinal Employer-Household Dynamics (LEHD)
 - LEHD Origin-Destination Employment Statistics (LODES)
 - Origin-Destination (OD)
 - Residence Area Characteristics (RAC)
 - Workplace Area Characteristics (WAC)
- Google Maps/Earth
 - Imagery
 - Street View
- esri
 - World Imagery Basemap

3.1.2 Created Data

Creation of several of the potential transit projects started with existing data which was used as a template for extraction and/or creation of new data. The other data was created by using Google Maps/Earth Imagery, Google Street View, and esri World Imagery Basemap to make features that connect to, or align with, real world infrastructure and natural features. In the end, eight features were created for a total of five potential transit projects.

Created Features for Potential Transit Projects by Project:

1. Beltline Light Rail Transit and Bike/Pedestrian Path
 - a. Beltline Light Rail Transit
 - b. Beltline Bike/Pedestrian Path
2. Heavy Rail Transit
 - a. Heavy Rail Transit Lines
 - b. Heavy Rail Transit Stations
3. Highway Cap Park Light Rail Transit and Path
 - a. Highway Cap Park Light Rail Transit
 - b. Highway Cap Park Bike/Pedestrian Path
4. Streets Light Rail Transit
5. Greenway Bike/Pedestrian Paths

3.2 Methods

The preparation of existing data and the creation of new data were performed using esri's ArcGIS 10.3. Next, an interactive python script was written using Pyscripter to assess the potential transit projects and then prioritize them according to user input.

3.2.1 Preparation of Existing Data/Creation of Potential Transit Projects Data

A file geodatabase was created with the projected coordinate system of WGS 1984 Web Mercator Auxiliary Sphere, which is the same system as ArcGIS Online basemaps and Google Maps/Earth. All existing data was then projected into that same

projection and placed into the file geodatabase. The LODES WAC jobs data, and the LODES RAC residents data CSVs were each joined to the Census 2010 Blocks feature class and then exported into new feature classes to make the joins permanent. Both LODES feature classes were then clipped to the combined area of Fulton, Dekalb, Clayton, and Cobb counties in order to shorten geoprocessing times involving them.

From the feature class Expressways, the inner and outer loops of Interstate 285 (I-285) were extracted and then extraneous sections, roads, and ramps were removed and missing/incorrect sections were repaired. Then, a polyline, a loop which ended up defining the final study area, was created halfway between the two polylines to approximate the location of the median. From this polyline was created a polygon, which was then used to clip all other interstates, railroad lines, and streets. The clipped interstates then went through the same steps as had already been performed on I-285 to produce polylines representing their medians.

In the Atlanta Beltline Corridor feature class, the loop polygon's inner and outer edges were clipped and smoothed to make the two sides more parallel. The polygon was then converted into two polylines and a third polyline was created halfway between them, which became the Beltline Bike/Pedestrian Path. This path was converted to a polygon and then buffered 20 feet. The outside of this buffer was converted to a polyline, which became the Beltline Light Rail Transit, completing the first potential transit project, the Beltline Light Rail Transit and Bike/Pedestrian Path.

The buffered Beltline polygon was used to erase the area inside of the Beltline loop of the previously clipped railroad lines and interstates, leaving the I-285 median line and the median of all interstates inside of the I-285 loop and outside of the Beltline loop

as part of the potential project Heavy Rail Transit Lines. In areas where there was a need for heavy rail transit, railroad lines were simplified and added to Heavy Rail Transit Lines. Heavy Rail Transit Stations were placed at the ends and intersections of all heavy rail transit lines, and at intersections with major roads, other transit, or near important sites. Together, the stations and lines make up Heavy Rail Transit, the second potential transit project.

The third potential transit project was made by selecting and exporting sections in the Streets feature class, along with manual digitization, to create a network of separated walking and biking paths alongside roadways. This Greenway Bike/Pedestrian Path potential transit project radiates out from the city center to I-285 and would be protected from motorized traffic.

Inside of the Beltline loop a network for the potential transit project Streets Light Rail Transit was created. Running mainly north/south and east/west, the lines in this fourth project run on the streets from the Beltline through the city to the Beltline on the other side of the city.

A cross-shaped multipart polygon representing a park was digitized over all interstates inside the Beltline loop. Also included in the park are any roads or parking lots/decks immediately adjacent to an interstate. Inside of this park, light rail transit runs along the edges in a north/south loop and in an east/west loop. An extensive network of walking and biking paths were digitized throughout the park. Altogether, the park, light rail transit, and the walking/biking paths make up Highway Cap Park Light Rail and Bike/Pedestrian Path, the final potential transit project.

3.2.2 Assessing the Sustainability of Potential Transit Projects

Each sustainability standard in this section is assigned a total of 100 points in the interactive Python script. Some standards have two parts, so each part is allotted 50 points. The points are awarded to each potential transit project according to how well it aligns with the sustainability standard compared to the other projects. Since several standards use walking distance as one of the sustainability measurements, all five projects were given a half mile buffer as the first step.

3.2.2.1 Spatial Integration of Employment and Transportation

The yardstick used for this standard is proximity to jobs. The potential transit projects are compared as to the number of jobs within walking distance of access to each project. The number of jobs in the blocks in the LODES WAC selected by each project's half mile buffer are summed and compared to the total number of jobs selected by all projects and then the 100 points are assigned on a percentage basis.

3.2.2.2 Pedestrian Access (Walking and Biking) to Work and Leisure

The first part of the assessment for this standard is proximity to residents. The potential transit projects are compared as to the number of residents within walking distance of access to each project. The number of residents in the blocks in the LODES RAC selected by each project's half mile buffer are summed and compared to the total number of residents selected by all projects and then the 50 points are assigned on a percentage basis.

The second part of the assessment is regarding protected pedestrian/bike corridors. The potential transit projects are given shares of the 50 points as to whether they have pedestrian and bike corridors and how protected they are from motorized traffic.

3.2.2.3 Protection of Natural and Biological Functions and Processes

The first part of the assessment for this standard is whether the potential transit project falls within a current transportation corridor. If the project falls completely within an existing transportation corridor, then no additional land would need to be taken to complete the new project. All five projects meet this standard equally well, so each receives 10 of the 50 points.

The second part of the assessment is whether the project minimizes pollution/greenhouse gases. Once completed, the project does not create new pollution/greenhouse gases and/or it breaks down or absorbs pollution/greenhouse gases. The projects are given shares of the 50 points as to whether they do not create new pollution, do not create new greenhouse gases, break down pollution, break down greenhouse gases, absorb pollution, or absorb greenhouse gases.

3.2.2.4 Social Spaces (Public Spaces to Encourage Social Gathering)

The measurement for this standard is proximity to both residents and jobs. No part of the Streets Light Rail Transit or Heavy Rail Transit systems was considered to be a public place to encourage social gathering, so these two projects received no points for this standard.

The first part of the assessment for this standard is proximity to residents. The potential transit projects are compared as to the number of residents within walking distance of access to each project. The number of residents in the blocks in the LODES RAC selected by each project's half mile buffer are summed and compared to the total number of residents selected by all projects and then the 50 points are assigned on a percentage basis.

In the second part of the assessment the potential transit projects are compared as to the number of jobs within walking distance of access to each project. The number of jobs in the blocks in the LODES WAC selected by each project's half mile buffer are summed and compared to the total number of jobs selected by all projects and then the 50 points are assigned on a percentage basis.

3.2.2.5 Inter-Modal Transportation Connectivity

The measurement for this standard involves the number of different types of transit connections for each potential transit project. All potential transit projects are buffered by 500 feet (1 city block \approx 300 feet) and the different types of transit that had access points within this buffer of each other are considered connected. The potential transit projects are then compared as to the total number of different types of transit to which they are connected. The total different types of transit connections for each project is compared to the total number of different transit type connections for all projects and then the 100 points are assigned on a percentage basis.

3.2.2.6 Potential Transit Projects Sustainability Scores

Once all of the potential transit projects have been assessed against all of the sustainability standards, the points earned for each project are summed resulting in a final sustainability score for each project.

3.2.3 Prioritizing Potential Transit Projects

The prioritization of the potential transit projects starts with an interactive section of the Python script that prompts users to respond to a series of statements that pop up on the screen relating to each sustainability standard, or for standards that have two parts: for each portion of each sustainability standard:

- The first statement that appears is an explanation of what is to follow:

“Please rate each of the following statements as to how important it is to you by entering a number from 1 to 10, with 1 meaning ‘Not at all important’ and 10 meaning ‘Extremely important’. Click OK to continue”

 - Any response will cause the script to proceed to the next statement.
- “1: Having access to transit within walking distance of my JOB”
 - For this, and any of the following statements, any response that is not an integer from 1 to 10 inclusive will produce the following statement to appear in the interactive window: “YOUR INPUT MUST BE AN INTEGER FROM 1 TO 10” and the original statement pops back up for the user to enter a correct response.
- “2: Having access to transit within walking distance of my HOME”
- “3: Having walking/biking greenway paths that are separated from motorized traffic for commuting to work or for recreation”

- “4: That future transit projects do not take additional land or disturb natural processes”
- “5: That future transit projects do not pollute/emit greenhouse gases and/or they absorb/break down pollution/greenhouse gases”
- “6: Having public spaces for recreation, socializing, or just to be around other people within walking distance of my HOME”
- “7: Having public spaces for recreation, socializing, or just to be around other people within walking distance of my JOB”
- “8: Having interconnected networks of many different types of transit to choose from”

Once the user has rated all statements, the numbers entered for each statement are multiplied by the values calculated for each corresponding standard or portion of a standard for each potential transit project in the previous sustainability assessment. All of these scores are summed by potential transportation project, the projects are sorted from highest to lowest, and then the name and a description of each potential transit project is printed in ranked order in the interactive Python window.

CHAPTER 4. RESULTS

4.1 Sustainability Scores

The overall sustainable development scores for each potential transit project:

<u>Potential Transit Project</u>	<u>Sustainability Score</u>
Greenway Bike/Pedestrian Path	223.63883853
Highway Cap Park Light Rail and Bike/Pedestrian Path	102.261134896
Beltline Light Rail Transit and Bike/Pedestrian Path	65.2812034501
Streets Light Rail Transit	56.7096465411
Heavy Rail Transit	52.1091765799

4.2 Prioritization

The results of the interactive prioritization section of the Python script would depend upon the importance that the user assigned to each statement that was presented to them. A sample output of prioritization results is presented below.

[illegible]

The few people who have used the script so far have shown interest, curiosity, and/or surprise at the results, with some even expressing consternation when the project that they would most like to be built was not prioritized at the top of the list the first time they ran the script.

CHAPTER 5. DISCUSSION

5.1 Performance

The purpose of the project was to determine whether potential transit projects could be assessed for alignment with sustainable development standards and then prioritized according to user preferences using GIS and an interactive Python script. The final script performs as intended and produces consistent sustainable development scores for each of the potential transit projects. The priority of the projects changes as the user varies the importance of the statements presented, as expected. Due to its very high sustainability score compared to the other projects, the Greenway Bike/Pedestrian Path was the top priority project nearly every time, regardless of user preference input. The Highway Cap Park Light Rail and Bike/Pedestrian Path was likely to be prioritized in the top three due to having the second highest score. This project shows that GIS, combined with an interactive Python script, can be used on potential transit projects to automatically assess for sustainability and then prioritize according to user input.

5.2 Limitations

Even though the project showed that the initial goals were met and that the concept works, the results are sensitive to decisions made while setting up the original parameters. For instance, the sustainability standards used were chosen from themes found in current literature regarding sustainable development, however, a different interpretation of what those standards should be could affect the sustainability ratings. Likewise, selecting different yardsticks to determine whether a project met the chosen sustainability

standards could lead to different sustainability scores. In the interactive prioritization section, slight variations in the wording of the statements presented could change how users respond, thus changing the final order of the projects.

5.3 Future Directions

Having advisors and other researchers review the project components during development and then test the finished product prior to its general use could have helped to prevent unintentional incorporation of any possible biases of the principal researcher into the structure or wording of the project. Making the Python script into a tool could make it easier to use for anyone not familiar with Python. Since the script seemed to trigger engagement in the limited number of people who used it, in the future, a larger number of different users could be allowed to use the script to obtain reactions and assess engagement with the topic before and after use. In order to make their choices when interacting with the script more impactful, the results of their prioritization could be tied to a map that would change according to user input, with the highest priority project being presented in deep rich colors, and then the other projects presented as progressively more faded until the lowest rated project would be 90% transparent. This, combined with the descriptions that are printed to the screen in the Python window, could help users understand what the potential projects encompass, how they are related to each other, and how the users' inputs are related to the resulting prioritization.

WORKS CITED

WORKS CITED

- Corning, Sarah E., Rasul A. Mowatt, and H. Charles Chancellor. 2012. "Multiuse Trails: Benefits and Concerns of Residents and Property Owners." *Journal Of Urban Planning & Development* 138, no. 4: 277-285.
- Dalton, Alice M., Andrew P. Jones, Jenna R. Panter, and David Ogilvie. 2013. "Neighbourhood, Route and Workplace-Related Environmental Characteristics Predict Adults' Mode of Travel to Work." *Plos ONE* 8, no. 6: 1-11.
- Djurhuus, Sune, Henning S Hansen, Mette Aadahl, and Charlotte Glümer. 2014. "The association between access to public transportation and self-reported active commuting." *International Journal Of Environmental Research And Public Health* 11, no. 12: 12632-12651.
- Griffith, Janice C. 2011. "Green Infrastructure: The Imperative of Open Space Preservation." *Urban Lawyer* 43, no. 1: 259-306.
- Handy, Susan L., and Yan Xing. 2011. "Factors Correlated with Bicycle Commuting: A Study in Six Small U.S. Cities." *International Journal Of Sustainable Transportation* 5, no. 2: 91-110.
- Heinen, Eva, Jenna Panter, Roger Mackett, and David Ogilvie. 2015. "Changes in mode of travel to work: a natural experimental study of new transport infrastructure." *International Journal Of Behavioral Nutrition & Physical Activity* 12, 1-10.
- Jepson Jr., Edward J., and Mary M. Edwards. 2010. "How Possible is Sustainable Urban Development? An Analysis of Planners' Perceptions about New Urbanism, Smart Growth and the Ecological City." *Planning Practice & Research* 25, no. 4: 417-437.

- Jones, Caroline H. D., and David Ogilvie. 2012. "Motivations for active commuting: a qualitative investigation of the period of home or work relocation." *International Journal Of Behavioral Nutrition & Physical Activity* 9, 109-120.
- Kim, Kyeongsu, and Michael L. Lahr. 2014. "The impact of Hudson- Bergen Light Rail on residential property appreciation." *Papers In Regional Science* 93, S79-S97.
- Loukaitou-Sideris, Anastasia, Harrison Higgins, Dana Cuff, and Dan Oprea. 2013. "Up in the Air: Urban Design for Light Rail Transit Stations in Highway Medians." *Journal Of Urban Design* 18, no. 3: 313-339.
- Oh, Kyushik, Dongwoo Lee, and Changsug Park. 2011. "Urban Ecological Network Planning for Sustainable Landscape Management." *Journal Of Urban Technology* 18, no. 4: 39-59.
- Silverman, David S. 2011. "Green Transportation: Roadblocks and Avenues for Promoting Low-Impact Transportation Choices." *Urban Lawyer* 43, no. 3: 775-778.
- Trowbridge, Matthew J, and Thomas L Schmid. 2013. "Built environment and physical activity promotion: place-based obesity prevention strategies." *The Journal Of Law, Medicine & Ethics: A Journal Of The American Society Of Law, Medicine & Ethics* 41 Suppl 2, 46-51.
- Wickizer, Benjamin J., and Andrew Snow. 2010. "Rediscovering the Transportation Frontier: Improving Sustainability in the United States Through Passenger Rail." *Sustainable Development Law & Policy* 11, no. 1: 12-62.
- Wilson, Lee-Ann, Billie Giles-Corti, and Gavin Turrell. 2012. "The association between objectively measured neighbourhood features and walking for transport in mid-aged adults." *Local Environment* 17, no. 2: 131.

- Wolf, Kathleen L., and Alicia S.T. Robbins. 2015. "Metro Nature, Environmental Health, and Economic Value." *Environmental Health Perspectives* 123, no. 5: 390-398.
- Zhang, Xingyou, Hua Lu, and James B Holt. 2011. "Modeling spatial accessibility to parks: a national study." *International Journal Of Health Geographics* 10, 31.